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An Experiment with the Wind Law in the NMC Objective Analysis Program

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

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I. Introduction

When the next generation of polar orbiting weather satellites, the TIROS-N series, becomes operational, the number of remote soundings available to the NMC objective analysis program will increase by nearly an order of magnitude. The number of soundings will be increased because the TIROS-N sounder will be capable of retrieving soundings through clouds and over land. Sounders currently in operation do not have such capability. Since remote sensors aboard TIROS N will produce atmospheric mass observations but no wind observations, the wind law of the objective analysis procedure will become increasingly important. Studies have shown that corrections made to the mass field are rapidly "forgotten" by large scale NWP models unless corresponding corrections are made to the motion field. Unless the analysis procedure used can correct the wind field in such a way as to effect a reasonable balance between mass and motion fields, ingestion of large numbers of remote soundings may be futile or perhaps even harmful.

The spectral objective analysis procedure used in the Operational and Final cycles at NMC (Flattery, 1970) has a wind law built into it. The wind law is derived from the set of equations governing the linear behavior of an atmosphere which is in a basic state of rest. This paper reports on a simple experiment designed to test how well the wind law works under the type of conditions which may be expected to occur when TIROS N is operational.

II. Experiment description and results

The type of conditions described in the previous section was simulated by analyzing observational data with all winds except surface winds excluded. Such a data base is an exaggeration of the kind of conditions that will exist operationally. However, it is likely that over some areas remote soundings will be available with little or no observational wind information; or if wind observations are available, they may be single level (e.g., aircraft and satellite cloud tracked winds).

The example chosen for this test occurred on August 22, 1975. Attention was focused on western North America where a significant change in the flow pattern occurred in a 24-hour period. This area is well covered by radiosonde stations. The density of radiosonde observations is similar to what can be expected from TIROS N at mid-latitudes. It is expected, however, that remote soundings from TIROS N will be somewhat less accurate than radiosonde soundings.

The NMC 500-mb analysis for 12 GMT August 21, 1975, is shown in Figure 1. A well-defined closed low existed at that time over central California. The main branch of westerlies over western North America was weak and to the north of the closed low. During the subsequent 24-hour period a rather strong short wave trough entered British Columbia from the Gulf of Alaska, causing the California low to open up and a substantial portion of it to "kick out" towards the northeast. By 12 GMT on August 22 (Figure 2) the westerlies over British Columbia and northwest United States had increased substantially and a closed center was in existence to the north of the strong westerlies. The area where the closed low had existed 24 hours earlier filled by about 50 m.

Both analyses shown so far had the benefit of all available wind data. The analysis from 12 GMT August 22 was then rerun, excluding all wind data and using the analysis from 12 GMT August 21 as first guess. The purpose was to see whether or not a "poor" first-guess wind field (i.e., off time by 24 hours) could be corrected by a dense network of mass-only observations. The answer is yes, as can be seen by comparing the first two columns in Table 1. The second column depicts the root-mean-square vector wind error of such an analysis when verified against 26 western North American radiosonde stations. The first column shows verification of the guess field against the same set of stations. The verification stations are shown in Figure 3. The analysis verifies better than the guess at all levels except 850 mb where 24-hour persistence is better than an analysis without benefit of wind data. At 500 and 300 mb the improvement over the poor first-guess is substantial. A subjective assessment of the balance can be made by examining Figure 4., which depicts height contours in meters and analyzed wind barbs in meters/second.

It is possible in the analysis program to vary the degree to which the wind law is enforced. If it is enforced strictly, a poor fit to observations results since the wind law is more nearly geostrophic than the real atmosphere. If it is not enforced at all, a poor balance can result in areas where either mass or motion observations are absent and large corrections to the first-guess are made. Furthermore, it is possible to enforce the wind law more strictly for one data type, such as remote sounding data, than for other data types.

To see if such a tactic might be advantageous, the analysis was rerun with a strict application of the model wind law. Again a "poor" (24-hour old) first-guess was used and all upper level wind observations were excluded. This analysis simulates what could be done in areas of good remote sounding coverage but poor wind data coverage. This analysis was verified in the same manner as the first. Comparison of columns 2 and 3 in Table 1 shows that a somewhat better fit to radiosonde winds occurs at 500 mb and 300 mb, but that the fit is slightly worse at the lowest and highest levels than the first analysis. Heights and analyzed winds at 500 mb for this second analysis are depicted in Figure 5.

A third analysis was performed with yet another application of the model wind law. In the third analysis height and wind correction coefficients to the analysis were blended with one another on the first seven iterations of the analysis. (Nine iterations are performed in all.) An 80/20 blending formula was used. That is, corrections to the height coefficients consisted of 80% weight from height correction coefficients and 20% from wind correction coefficients. Corrections to the wind coefficients consisted of 80% weight from wind correction coefficients and 20% from height correction coefficients. The resulting wind errors at the radiosonde stations are shown in Table 1, column 4. Comparing column 4 to columns 2 and 3, it can be seen that the errors are slightly smaller overall than those of the operational analysis but larger than those of Case 2. Heights and analyzed winds for this case are shown in Figure 6.

On the basis of these three analyses it can be concluded that the model wind law is capable of making substantial corrections to a poor first-guess wind field, given a dense network of high quality, mass only observations. Using a stricter application of the wind law than what is now used operationally produces slightly better corrections at 500 and 300 mb, but slightly worse results at low and high levels.

But what about the more usual case when the first guess is very nearly correct and needs only a small amount of changing? In order to answer this question, the previous three analyses were rerun using a "good" first-guess. The first-guess was a 6-hour global forecast valid at 12 GMT August 22. Again all wind observations above the surface were excluded. All three wind analyses were verified against the same set of radiosonde stations used in Table 1. Results are tabulated in Table 2, along with verification of the first guess used. The first guess verifies best at all levels except 300 mb where the case 1 (operational) and case 3 (blended correction) analyses exhibit slightly smaller errors. The case 2 analysis (strict application of the wind law) verifies worse than the first guess or either of the other two analyses at all levels. Overall, cases 1 and 3 are only slightly less accurate than the first guess. The three 500-mb analyses which began from the "good" first guess are shown in Figures 7, 8, and 9. The plotted winds again are analyzed winds in meters per second.

In all the analyses performed in this experiment, the heights verified essentially the same (Table 3) regardless of how the wind law was enforced or what first guess was used. Such a result should be expected since many height observations were available at all levels over the verification area. The analysis procedure tends to draw for the observations in data rich areas regardless of what first guess is used. Observed winds did not influence the height analyses since they were excluded.

III. Conclusion

Results of this experiment suggest that the NMC spectral analysis model can and does make substantial improvement to a "poor" first-guess wind field when high density, mass only observations are used. Using a more strict application of the model wind law than is now used operationally does not improve the wind analysis very much. If a "good" first guess is used, a strict application of the wind law produces winds which verify worse than the first guess at all levels. The wind law, as currently used operationally, produces wind fields which verify nearly as well overall as the "good" first-guess winds.

These results suggest what influence the next generation of operational remote satellite soundings will have on the NMC operational analysis program. In areas where very few multi-level wind observations are available (mostly oceanic areas), remote soundings will have a correcting influence on the first-guess winds. However, in areas where the first-guess wind field is known to be quite accurate (immediately downstream from areas rich in wind observations), remote soundings probably will not cause an improvement to the first-guess wind field. Since remote soundings from TIROS N will not be as accurate as radiosonde observations, analyzed winds obtained using remote sounding data will probably be less accurate than the winds derived from radiosonde heights in this set of experiments.

Finally, enforcing the model wind law more strongly for remote soundings than is now the current practice will improve the wind analysis where the first guess is "poor" and wind observations are absent. However, in areas where the first guess is "good" such a practice will tend to degrade the first-guess wind analysis.

REFERENCES

Flattery, T. W., 1970: Spectral models for global analysis and forecasting. Proc. Sixth AWS Technical Exchange Conference, U.S. Naval Academy, Annapolis, Maryland, Air Weather Service Tech. Rpt. 242, 42-54.

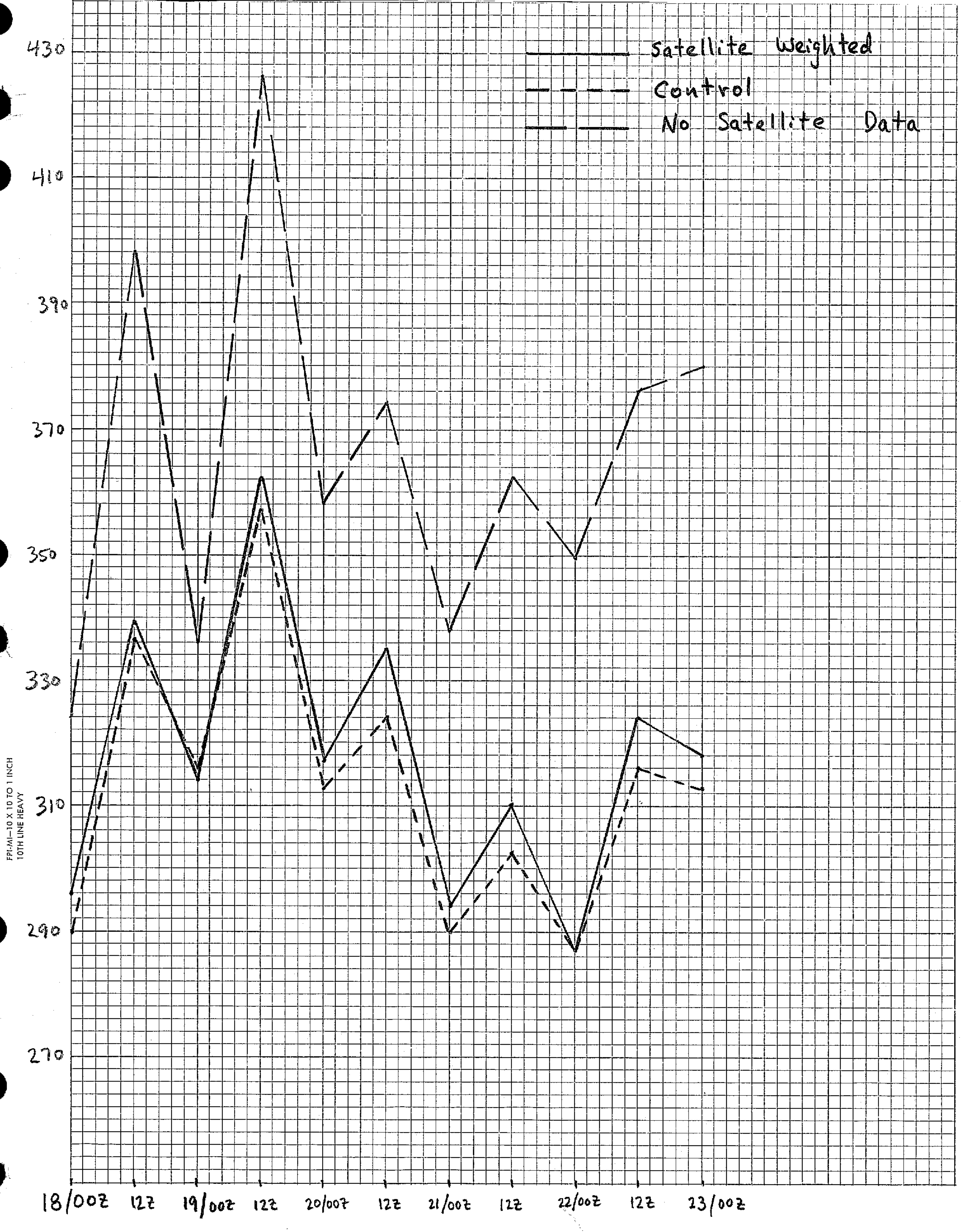
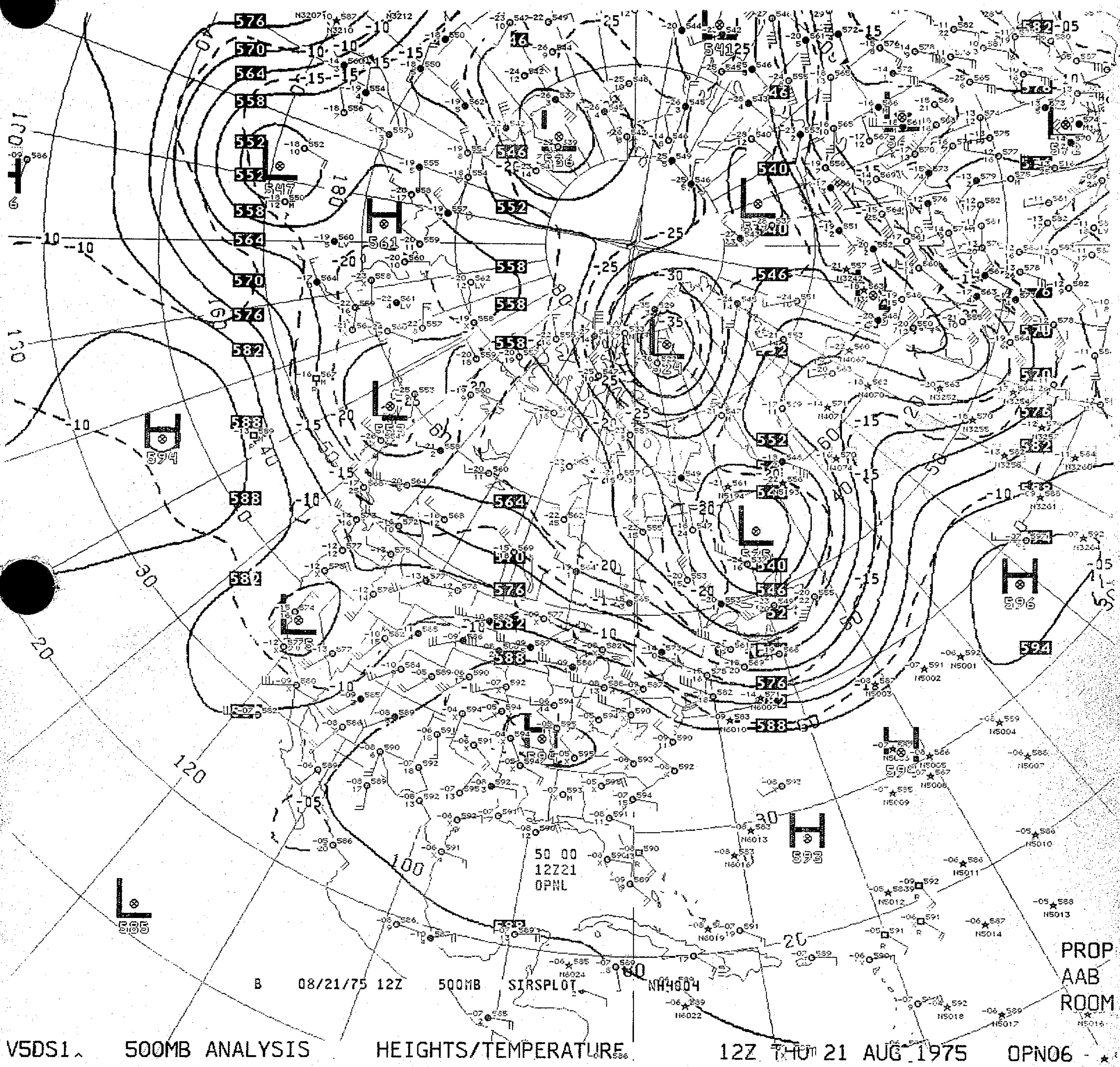


Figure 7. Eddy available potential energy (j/m^2)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V5DS1 500MB ANALYSIS HEIGHTS/TEMPERATURE 12Z THU 21 AUG 1975 OPN06

Figure 1.

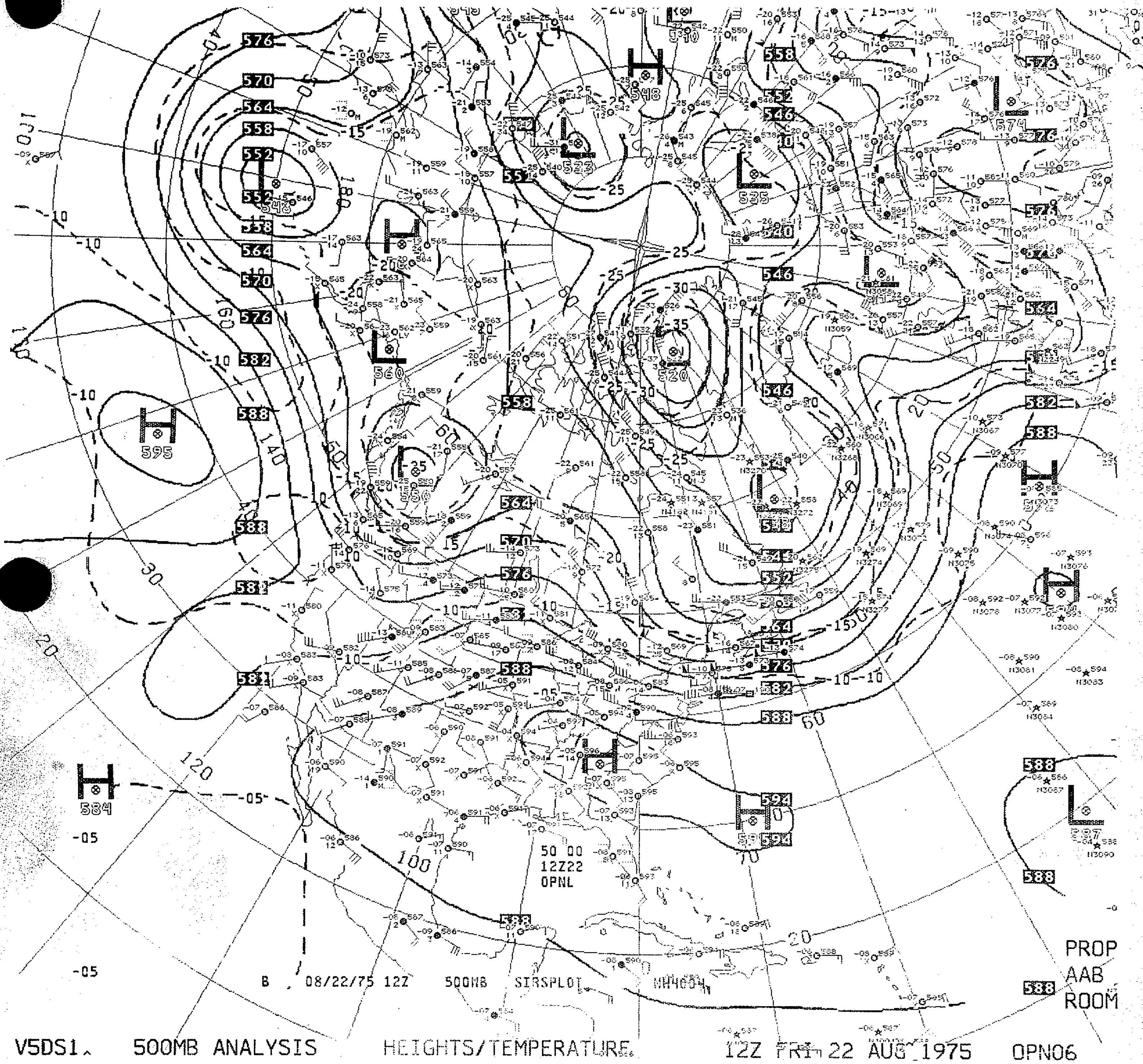
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Figure 2.

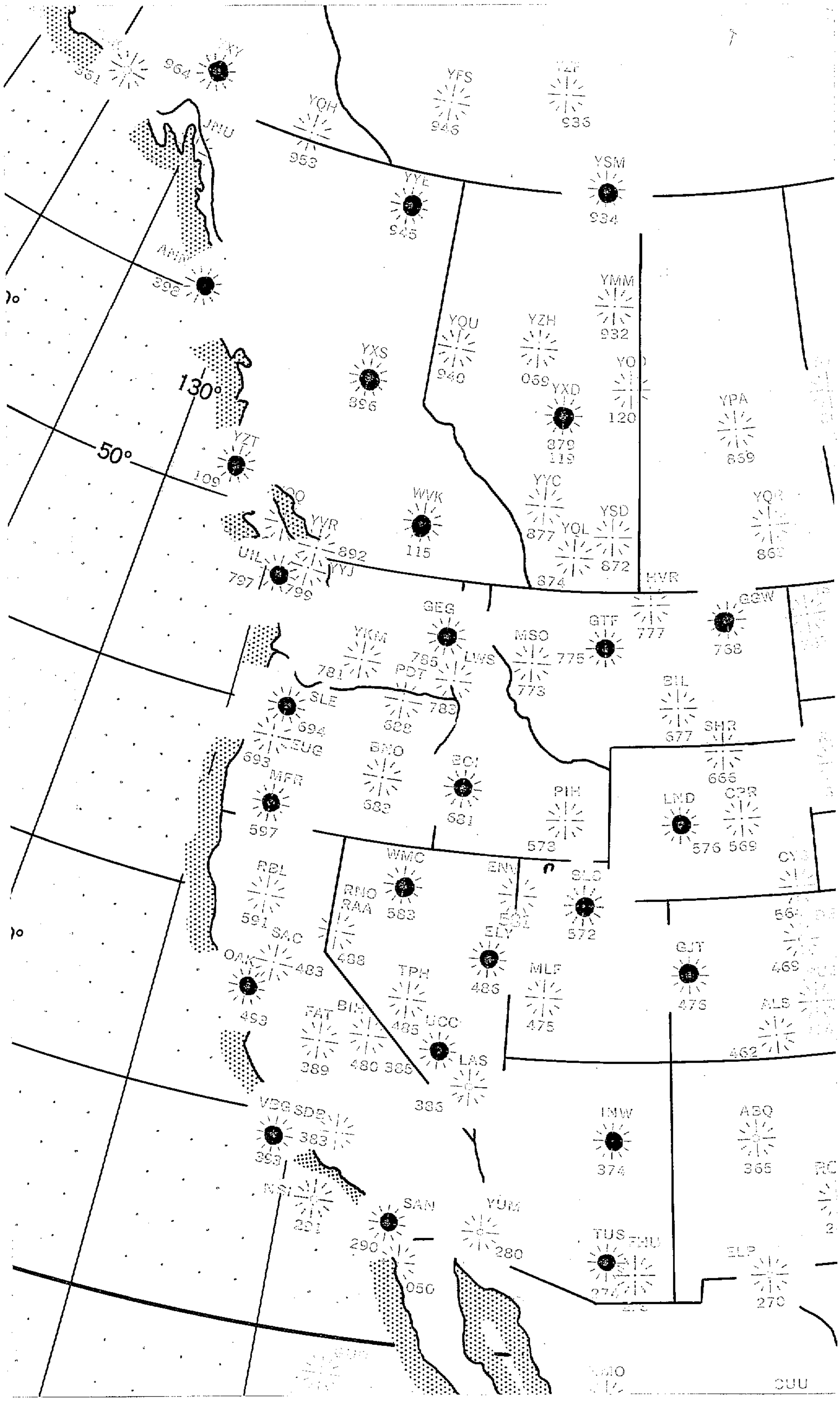

Figure 3. Verification Stations.

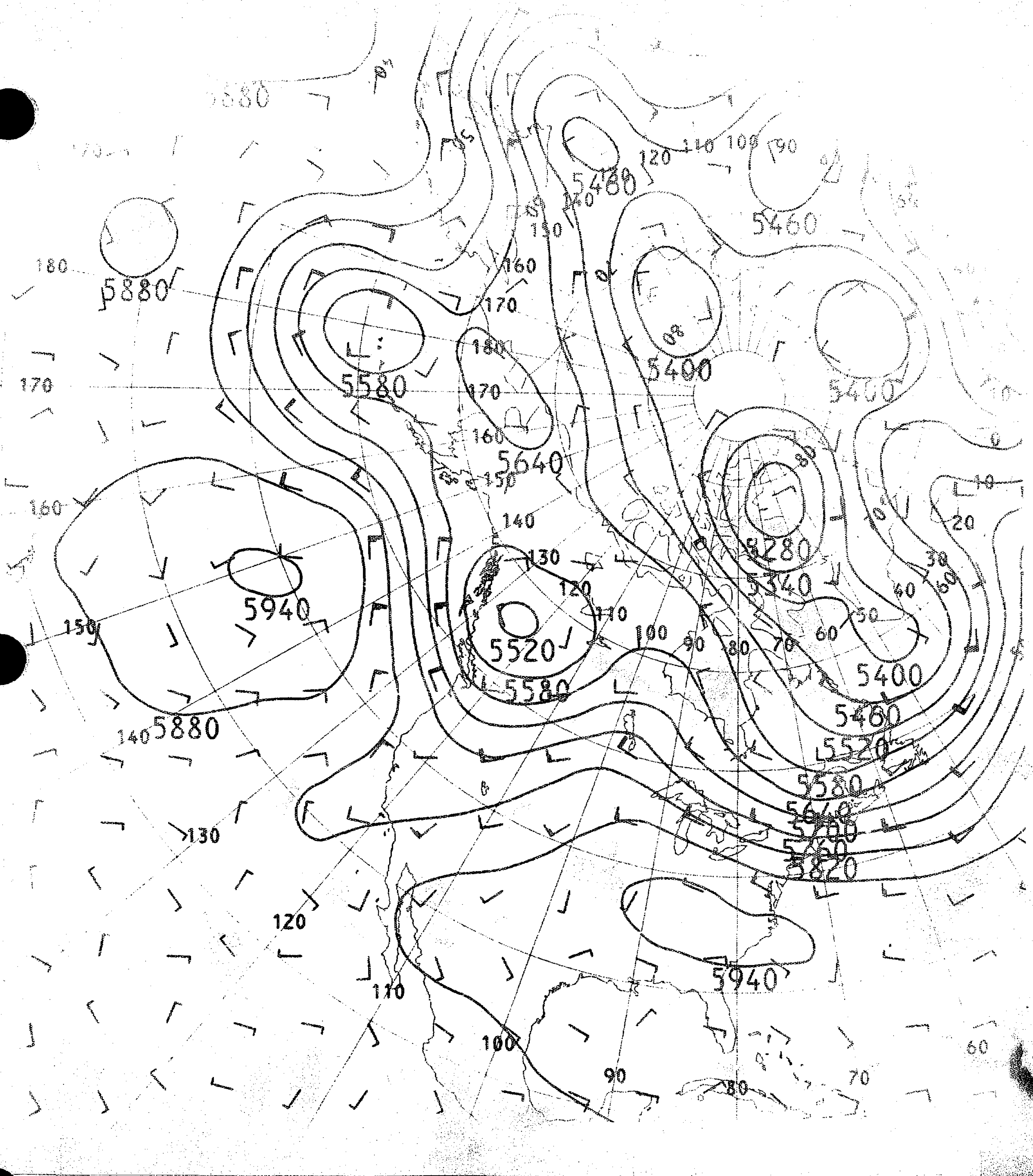

Figure 4. 500 mb analysis, operational wind law, "poor" guess.

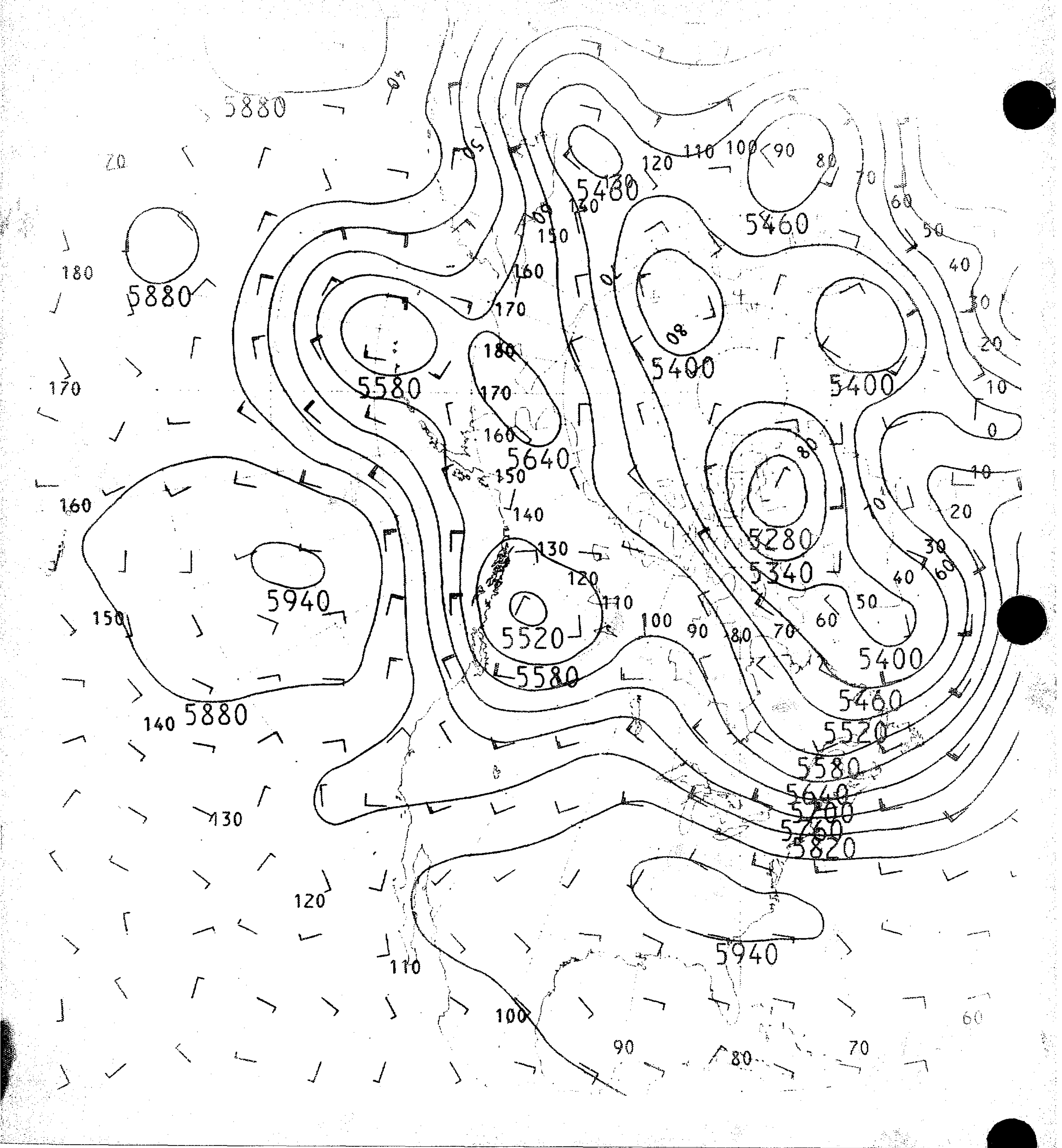

Figure 5. 500 mb analysis, strict wind law, "poor" guess.

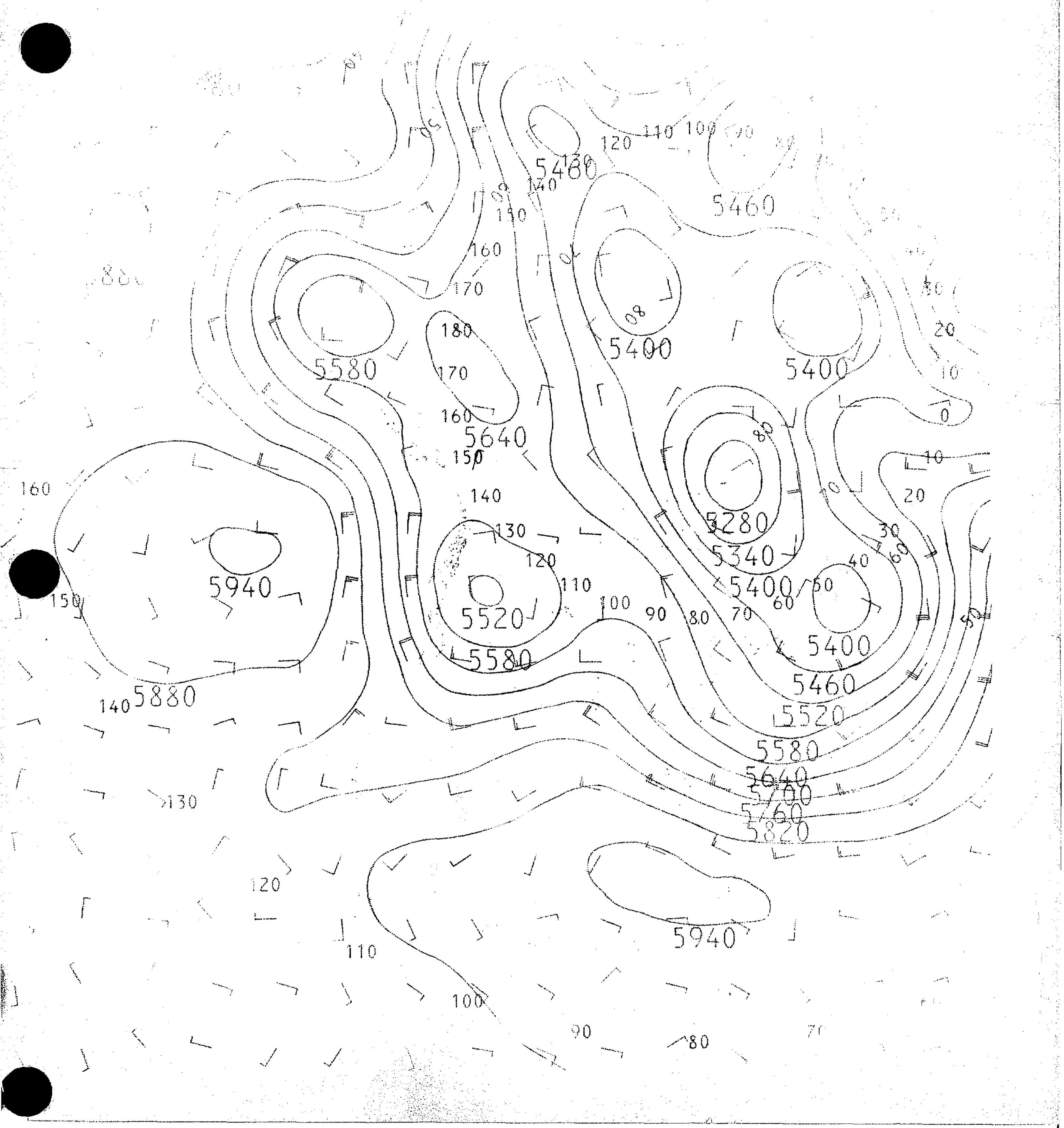

Figure 6. 500 mb analysis, blended corrections, "poor" guess.

Figure 6. 500 mb

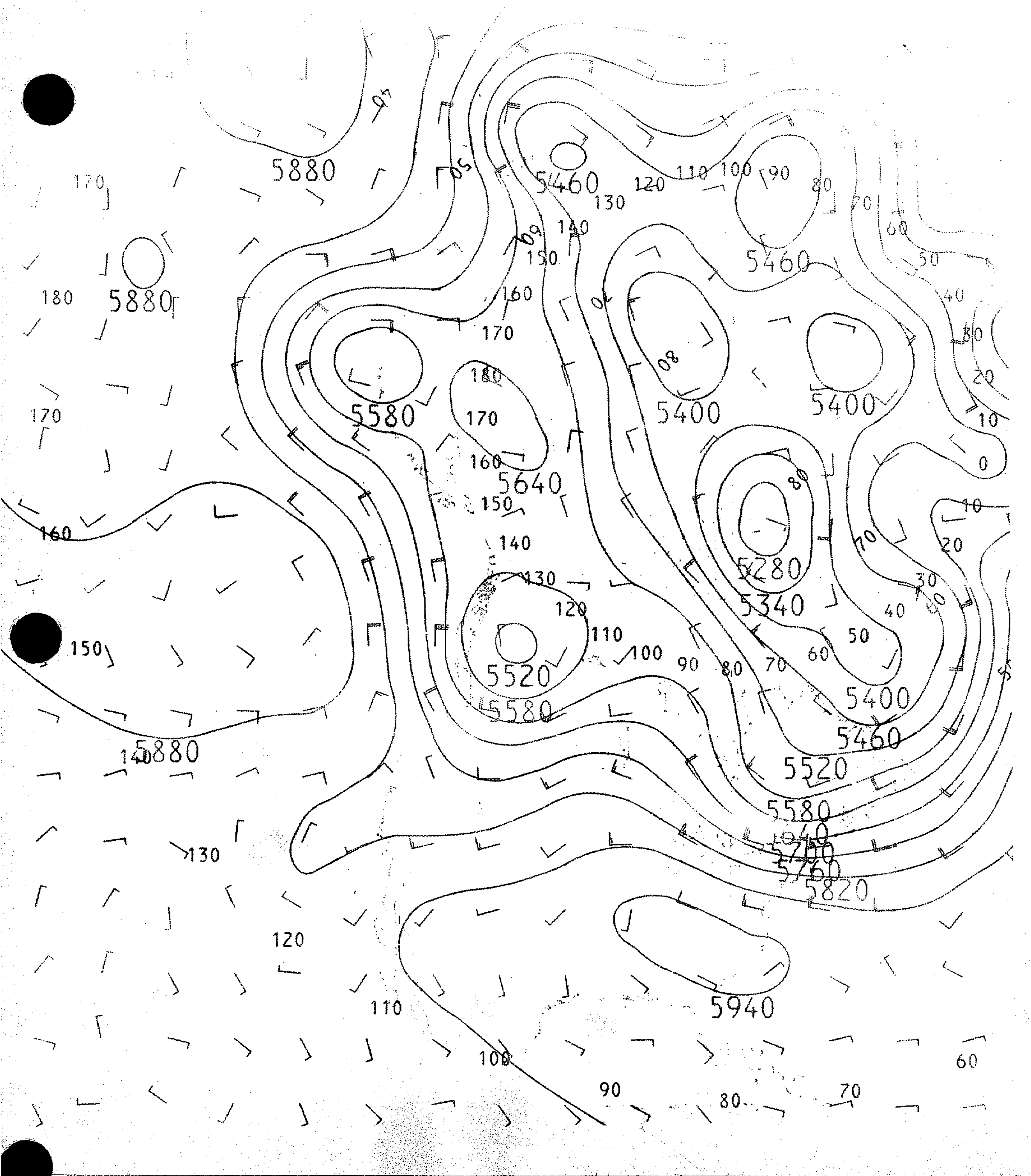

Figure 7. 500 mb analysis, operational wind law, "good" guess.

Figure 7. 500 mb analysis, operationa;l

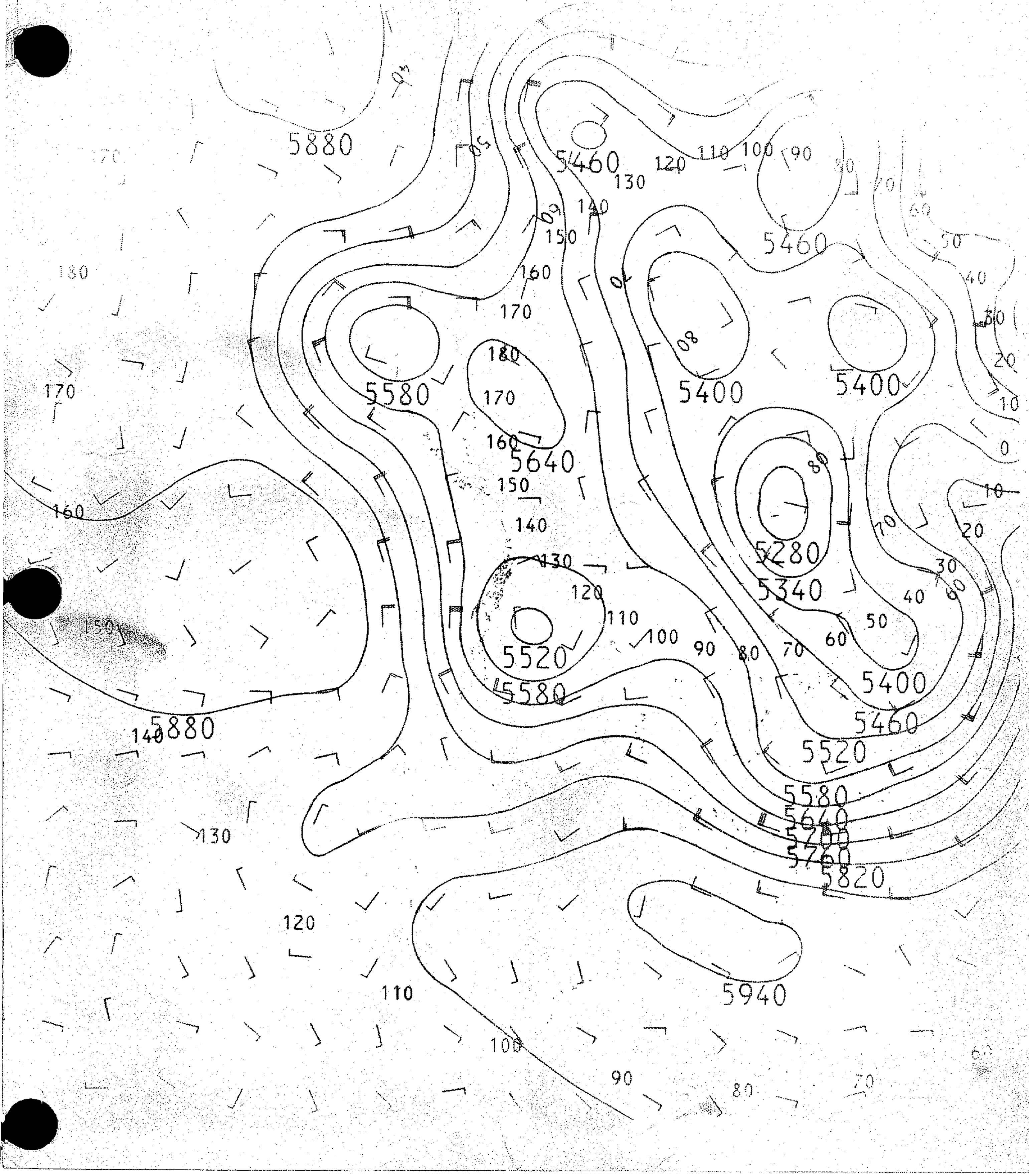

Figure 9. 500 mb analysis, blended corrections, "good" guess.

Figure 9. 500 mb analysis, blended corrections, "good" guess.

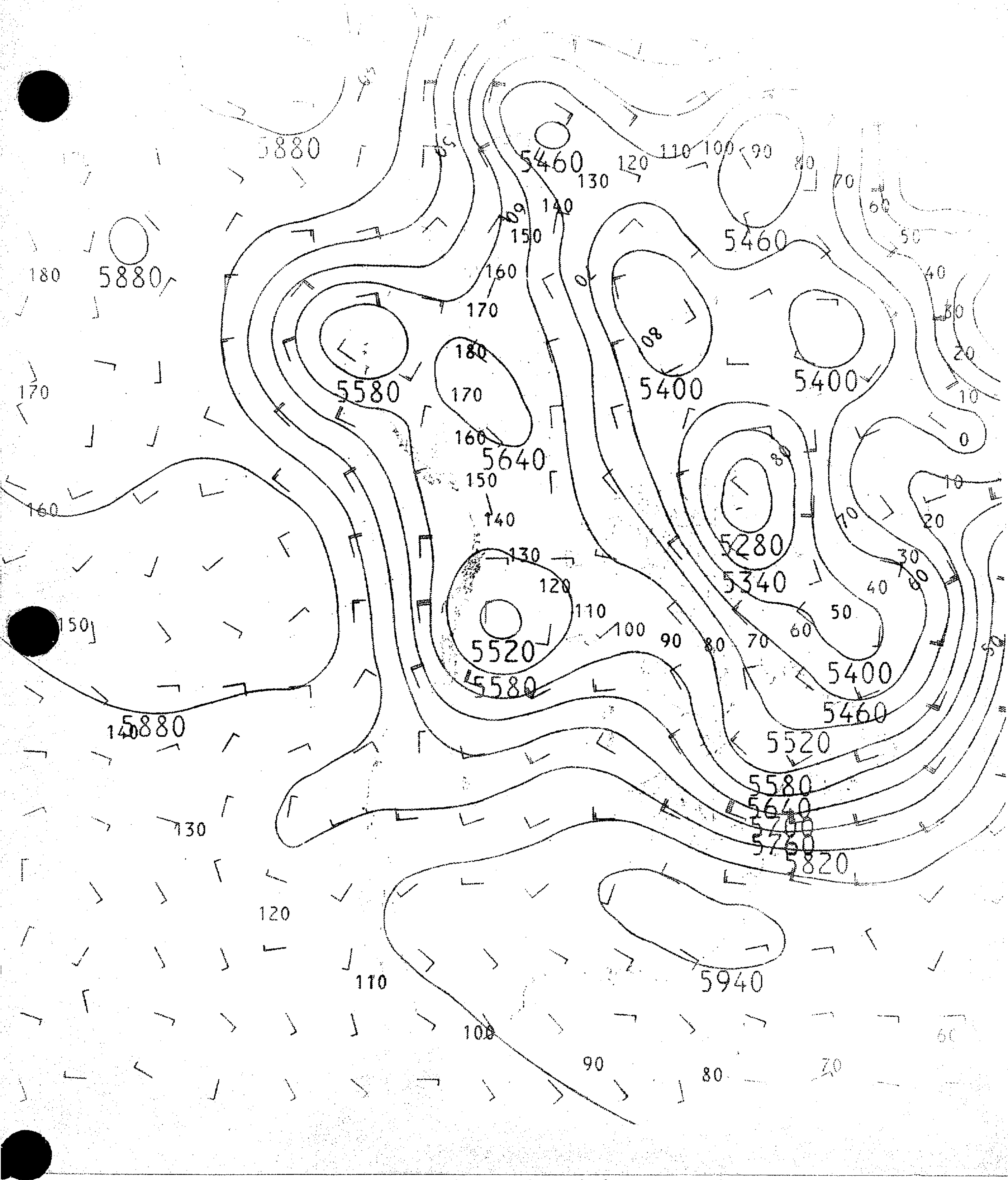

Figure 8. 500 mb analysis, strict wind law, "good" guess.

48-HR PRECIPITATION FORECASTS Vs OBSERVED 12-HR ACCUMULATIONS

VALID TIME 1200GMT 26 DECEMBER 1975

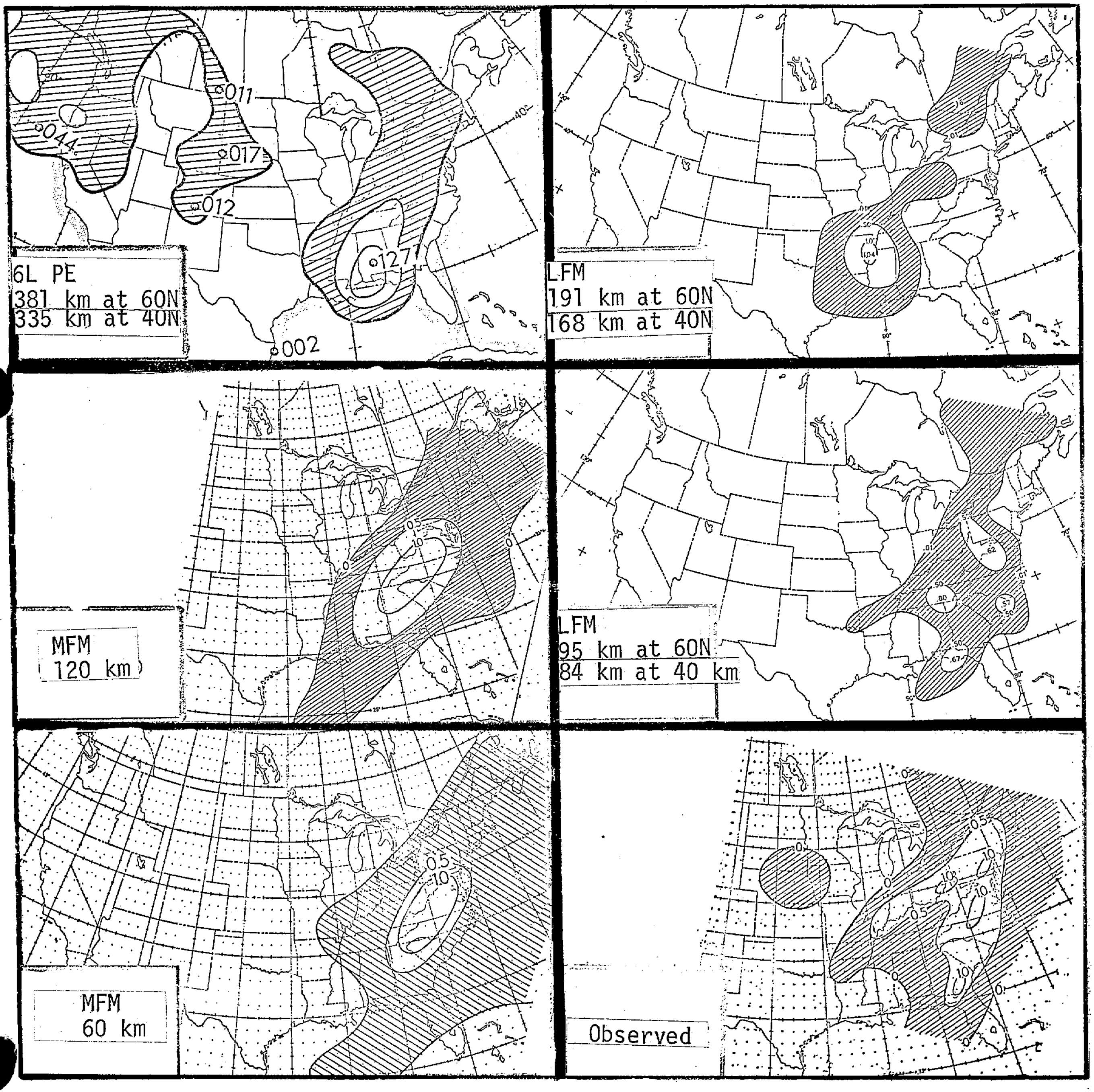

Figure 4

FIVE-DAY MEAN TEMPERATURE SKILL SCORES

DAYS 2-6 3 Winters 1966-69 Official (36) (Man modified)	DAYS 1-5 Winter 1976-77 Official (13) (Man modified)	DAYS 1-5 Winter 1976-77 Objective (15) (Machine guidance)	DAYS 6-10 Persistence of Official Days 1-5 Forecast* (13)	DAYS 6-10 Persistence of Objective Days 1-5 Forecast (15)	DAYS 6-10 Winter 1976-77 Subjective (15) (Man interpretation)
18.9	46.7	22.1	14.4	10.8	18.2

FIVE-DAY MEAN PRECIPITATION SKILL SCORES

DAYS 2-6 3 Winters 1966-69 Official (36) (Man modified)	DAYS 1-5 Winter 1976-77 Official (7) (Man modified)	DAYS 6-10 Winter 1976-77 Subjective (10) (Man interpretation)
16.8	26.9	15.0

Number of Cases Shown in Parenthesis

*Not Available When Subjective 6-10 DAY Forecast Was Made

Figure 5